The Influence of Weather in Determining the Probability of Detecting an Object in Distress during SAR Operations

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Abstract:

Purpose: *Planning an effective rescue operation is a subject of many factors. The success of SAR operation depends primarily on the accuracy of the information received and the conditions on the scene. Due to the impossibility of eliminating the danger and risk of accidents at sea, it becomes necessary to prevent and minimize their possible consequences to the greatest extent possible. The basic idea of the study is to develop a research scheme to estimate both the most likely position of an object in distress and to determine the possibility of a successful SAR operation.*

Design/Methodology/Approach: *The research was carried out using the SAR Navi-Harbour. TRANSAS 5000 module to plan and monitor rescue actions in a selected area. Simulations of conducting SAR operations were designed in the Baltic Sea area using the actual available SAR equipment.*

Findings: *This paper presents the influence of various factors on the effectiveness of SAR operations. It determines the probability of object detection (POD) and the likelihood of success (POS) for different weather condition scenarios that allow an analysis of the effectiveness of used SAR equipment and chosen searching patterns, which directly impact the success of the SAR operation.*

Practical Implications: *The results obtained in the simulations support the decision-maker at all stages of SAR rescue planning. The use of the simulation method becomes an alternative to the traditional way of planning.*

Originality/Value: *The article shows the need to use available market simulators to support the whole SAR operation at each stage.*

Keywords: *SAR, VTS, SAR operations, POD, POS.*

JEL codes: *R40, R49.*

Paper Type: *Case Study.*

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1. Introduction

In recent years, there has been an increase of goods by sea transport, resulting in higher volumes of vessel traffic in shipping routes. There has been a need to regulate maritime activities in detail using administrative regulations and technical and quality standards to protect life at sea and the marine environment. Maritime transport to ensure the safety of navigation has been covered by international legal acts. Some of the most important international conventions include the SOLAS Convention and MARPOL Convention.

Accidents and incidents that occur during shipping are difficult to predict. Maritime transport is characterized by high risk. The average number of accidents has steadily increased over the past five years (Szubrycht, 2020). It is impossible to eliminate the danger and risk of accidents at sea, so it is necessary to prevent and minimize their possible consequences to the greatest extent possible. The safety of navigation is affected by several factors that determine the chances of survival and salvage of property in an emergency.

Coastal countries are forced to organize and equip marine rescue services capable of handling effective rescue operations and possessing an adequate analytical facility and knowledge to estimate the danger associated with a given risk. They should also have adequately prepared and equipped rescue services.

In case of danger at sea, the forces and resources of the Maritime Search and Rescue Service (SAR) are used. The legal basis for the operation of the Maritime Search and Rescue Service is the "International Convention for the Safety of Life at Sea SOLAS" (International Convention for the Safety of Life at Sea), drawn up on 1 November 1974 in London and the International Convention on Maritime Search and Rescue - International Convention on Maritime Search and Rescue, Hamburg, 27 April 1979. The activity of the SAR Service is primarily to assist and eliminate hazards in the waters under its responsibility. Its purpose is to coordinate and carry out rescue operations at sea, the removal of harmful oil substances, and underwater work (search, research).

Nowadays, there are many solutions for automatic SAR action planning. Computer programs that support marine rescue operations use probability theories and simulation methods. There are many such programs to help the SAR action planning process, such as SAROPS (Search and Rescue Optimal Planning System for the US Coast Guard), JAWS (Joint Automated Work Sheets), CASP (Computer-Aided Search and Rescue Planning). Most of these programs use the Monte Carlo method, which assumes a random dispersion of the values of a variable within fixed limits (Abramowicz-Gerigk and Burciu, 2015).

One such system is the Transas Navi-Harbour 5000. This system has a handy Module SAR function, which allows the user to plan and monitor SAR action. It meets IMO

requirements issued by ICAO-IAMSAR Manual Volume II for planning and tracking SAR activities based on current weather conditions and accessibility of safety equipment. The module enables both the control of search activities and the calculation of the probability of search success. The user can easily and quickly select appropriate action parameters from the set of previously entered data. On their basis, the effectiveness of the planned action is automatically calculated.

2. Literature Review

In this study, an accident was simulated to determine the probability of successful planned SAR action. The object in distress was placed in the Baltic Sea, which, due to its specificity, belongs to the areas of difficult navigation. The Baltic Sea's geographic, hydro-meteorological, and geographical conditions and the increasing intensity of traffic in this area create a risk of an accident. It is recorded that there are currently about 2000 ships in the Baltic Sea maritime area and about 3500 - 5500 ships monthly passing through the Baltic region (Szubrycht, 2020).

Accident data:
- Object in distress: a life raft with four persons
- Type of accident: very serious
- Date and time of incident: August 26, 2018, 21:44.
- Geographic position at time of incident: φ=54o 22.5'N, λ=015o 24.3'E
- Geographical region of the incident: Baltic Sea
- Body of water: sea waters
- Operational condition of the vessel at the time of the incident: fishing
- Consequence of the incident: sinking
- Weather at time of incident: variable wind strength.

In particular scenarios, the following available rescue equipment will take part in the SAR operation, navy helicopter W3WARM 505, rescue vessel SZKWAŁ and coast guard fast boat SG-216. The characteristics of the above-mentioned resources are presented in Table 1.

Table 1. *Characteristics of units used for SAR planning*

Type of plane	speed	Time in air	Ready to	Level of crew fatigue
Navy helicopter W3WARM 505	235 km/h	4h12min	15 min	Normal
Type of vessel	**speed**	**Time at sea**	**Ready to**	**Level of crew fatigue**
Rescue vessel SZKWAŁ(Kołobrzeg)	30 w	10 h	15 min	Normal
Coast guard fast boat SG-216 (Kołobrzeg)	20,9 w	12 h	15 min	Normal

Source: *Own creation.*

In order to determine the influence of wind on the movement of the object in the water, a hydro-meteorological data set over the Baltic Sea is presented using scenarios. An example of a scenario data set is presented in Table 2.

Table 2. *Weather conditions scenario*

Date	Time	Direction [°]/wind speed [kn]
28 September	15.00	225/32
	16.00	225/32
	17.00	236/31
	18.00	236/31
	19.00	236/31
	20.00	247/32
	21.00	247/32
	22.00	247/31
	23.00	247/32
29 September	00.00	247/33
	01.00	247/33

Source: *Own creation.*

Listed below hydro-meteorological conditions were assumed to be constant throughout the scenario to help determine the effect of wind and current on the probability of detecting an object in distress.

- visibility – 10NM
- sunrise – 6:33
- sunset -18:19
- drift speed error (ASW) – 0,3kts
- possible observation error (TWCe) – 0,42 kts

3. Research Methodology

In investigated accident scenario in order to determine the reference position, various wind force parameters were entered as well as current. Using the collected hydro-meteorological data in the area, the average surface wind (ASW) for chosen wind scenario was calculated. Figure 1 (a, b) shows a dialog box for entering wind parameters.

Using Tidal Current program (TC), it is possible to enter the current in the search and rescue area (Figure 2).

The success of the search and rescue operation depends primarily on the correct determination of the search area, which is significantly influenced by the wind drift acting on the drifting life raft or lifeboat. The influence of the wind is greater in this case than the influence of the current (Książkiwicz, 2018). Therefore, parameter of the current was assumed as a constant factor.

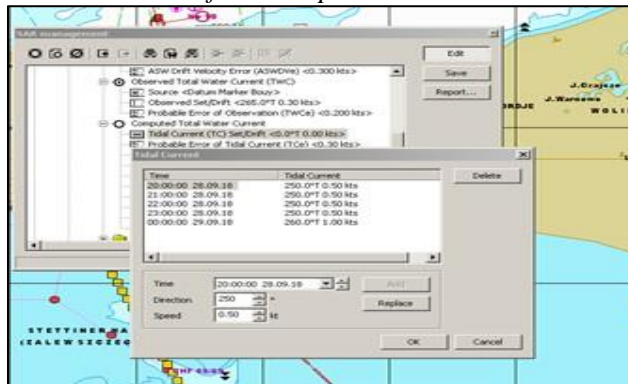***Figure 1a.*** *Introduction window of wind parameters and their changes –for no 1 scenarios*
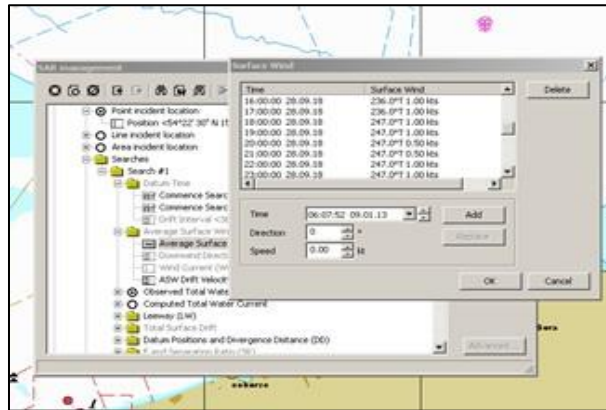
Source: *Own creation.*

Figure 1b*. Introduction window of wind parameters and their changes –for no 2 scenarios*
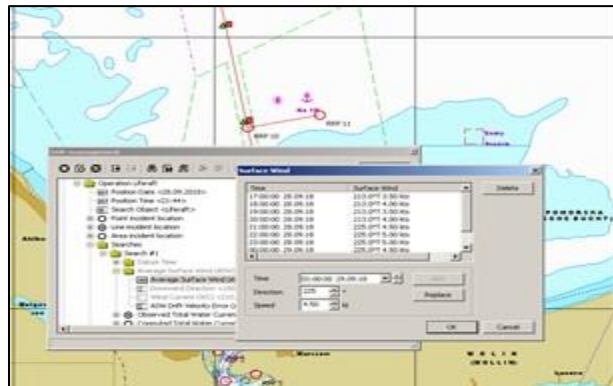
Source: *Own creation.*

***Figure 2.*** *Introduction window of current parameters and their changes.*

Source: *Own creation.*

Location of SAR Resources: Stand-by of SAR services is an essential element related to maritime transport and based on two forms of activity: the management and the executive parts. Both these parts at each stage of the SAR operation must cooperate. The management part is the responsibility of the Maritime Coordination Centre, whose task is to plan the SAR action and supervise the rescue activities. The executive function is passed to rescue units appointed by the Maritime Coordination Centre. Their purpose is direct search and rescue action. Each state, which has a coastline in its area, is obliged to control and coordinate rescue and search operations. The event referred to in the article occurred in Polish rescue service responsibility, which covers more than 30,000 km2.

Resource management is aimed at designating appropriate vessels to participate in SAR operations. One rescue helicopter and two rescue vessels were selected. In the SAR Module, the type of rescue craft was entered, and appropriate parameters were assigned to them (e.g., search speed, time of participation in the search, time remaining until sunset, correction factor taking into account crew fatigue). The following Figure 3 (a, b) shows the dialog box, using which it is possible to select the rescue facilities.

Figure 3a. *The selection of available rescue facilities.*
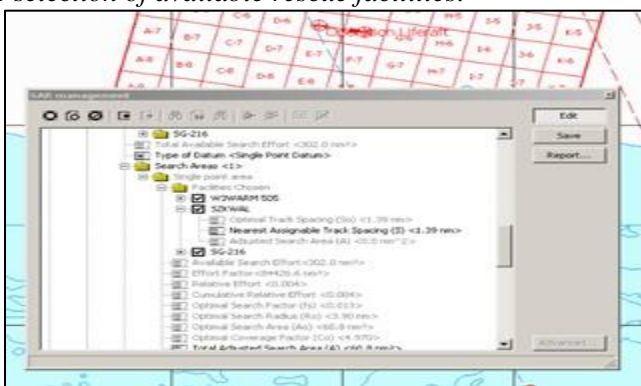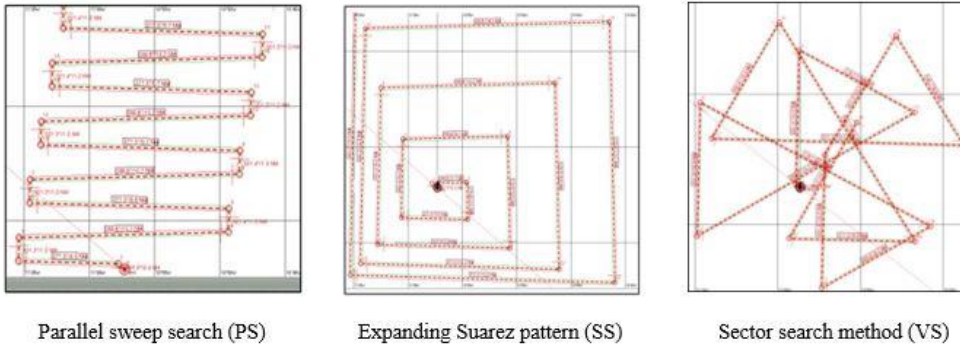

Source: *Own creation.*

Figure 3b. *The selection of available rescue facilities.*
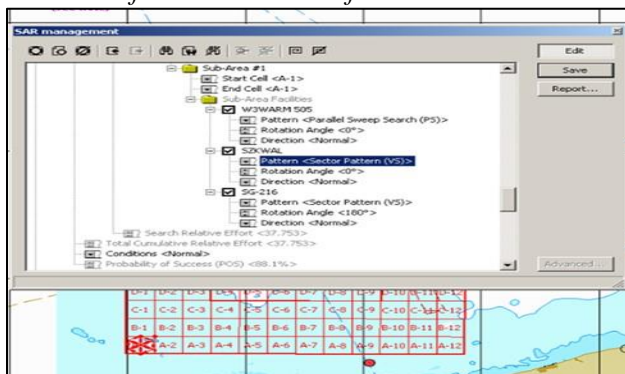
Source: *Own creation.*

Search Pattern Selection: The selection of the most effective searching pattern is made for various scenarios taking into account both, weather conditions and available SAR facilities (Figure 4). The search methods used are in accordance with IAMSAR guidelines.

Figure 4. *Examples of SAR methods used in Transas Navi-Harbour 5000.*

Parallel sweep search (PS)   Expanding Suarez pattern (SS)   Sector search method (VS)

Source: *Own creation.*

Table 3 shows the characteristics of selected scenario and the search pattern for each rescue unit.

Table 3. *Characteristics of selected scenario and the search pattern for each rescue unit.*

Nr.	Weather conditions			Rescue vessel – search pattern		
	Wind force	Boufort scale	Wind speed [knots]	m/v SZKWAŁ	Rescue boat SG-216	Helicopter W3WARM 505
1	Clam	0	>1			
2	Light air	1	1-5			
3	Light breeze	2	4-6			
4	Gentle breeze	3	7-10			
5	Moderate breeze	4	11-15	Sector search pattern (VS)	Sector search pattern (VS)	Parallel sweep pattern (PS)
6	Fresh breeze	5	16-21			
7	Strong breeze	6	22-27			
8	New gale	7	28-33			
9	Gale	8	34-40			
10	Strong gale	9	41-47			
11	Storm	10	48-55			
12	Violent storm	11	56-63			

Source: *Own creation.*

To determine the areas in which to look for an object in distress, the Monte Carlo method was used for the simulation. This method can select the search areas. This is used when looking for a thing when there are multiple independent random variables.

Probability of detection of an object and the probability of success of a SAR operation: The probability of detection (POD) detects a searched object, assuming that the thing is within the explored area. POD is a function of the Coverage factor, the search conditions, and the accuracy with which the search object moves through its assigned search pattern. It measures the effectiveness of the sensor under the prevailing search conditions. It is calculated automatically in the SAR Module. The probability of success (POS) is the probability of finding the searched object. POS is a measure of search effectiveness. The program automatically calculates the Cumulative Relative Effort, the sum of all previous efforts and the planned search, based on previously entered data. The result of each scenario is shown in Table 4.

Table 4. *Results of Probability of detection of an object and the probability of success of a SAR operation.*

Scenario number	POS	POD
01	97,4 %	67,8%
02	97,4 %	67,7%
03	97,2 %	67,7%
04	97,2 %	67,7%
05	96,9%	65,6%
06	96,7%	65,5%
07	95,6%	64,7%
08	94,1%	61,7%
09	93,3%	60,7%
10	90,8%	59,1%
11	87,3%	56,7%
12	86,8%	56,4%

Source: *Own creation.*

Figure 5 shows an example scenario with automatically calculated Cumulative Relative Effort values of 34.517 and a Coverage factor of 1.062.

Figure 5. *Example of calculated Cumalative Relative Effort and Coverange factor*
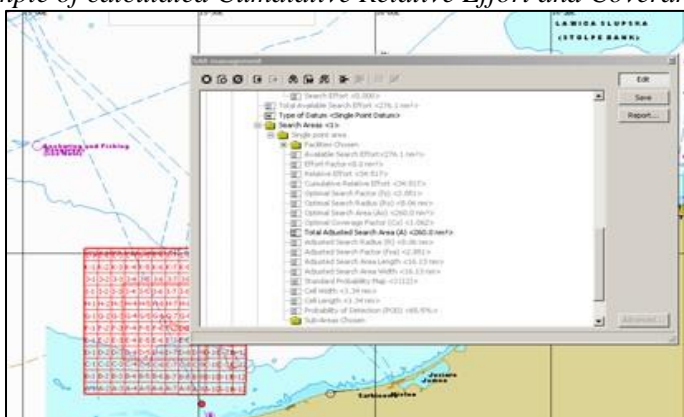
Source: *Own creation.*

4. Results and Discussion

The analysis of the results is based on the simulations performed using the SAR Module. The results obtained from the tests show the influence of the wind on the calculation of POD and POS. In the graph shown below, the relationship of the success in finding an object in distress with the wind strength in the area can be observed (Figure 6 and Figure 7). As the wind speed increases, both probabilities decrease. This is because the search area in which a rescue boat may be located begins to increase. This causes an increase in searching area.

Figure 6. *Relation between POS and wind speed*
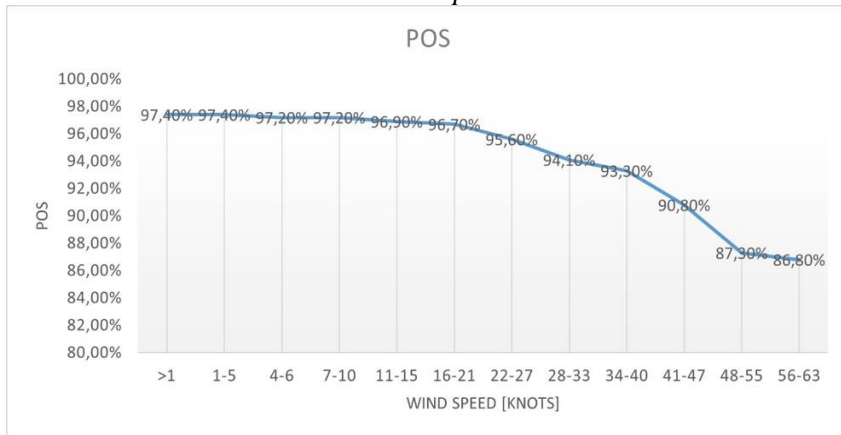
Source: Own creation.

**Figure 7.** *Relation between POD and wind speed*
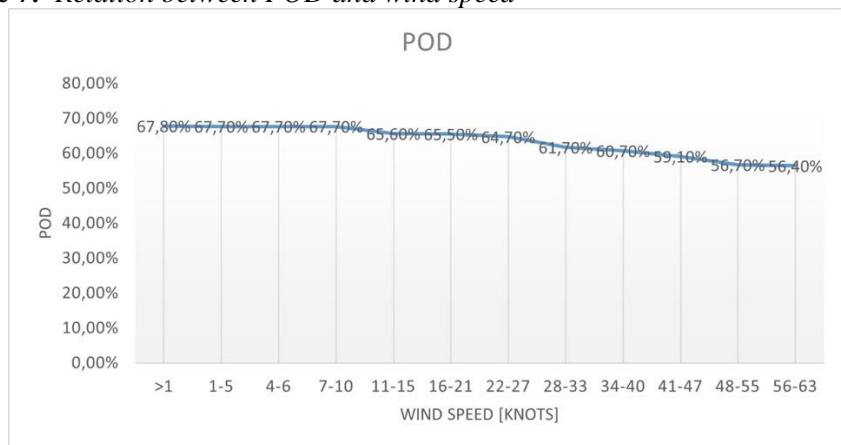
Source: Own creation.

Under strong wind conditions, the POD and POS are much lower. In calculating POD (probability of detection) and POS (probability of success), the program considers the information contained in the Appendices (L, M, N) of the IAMSAR Manual Vol. II
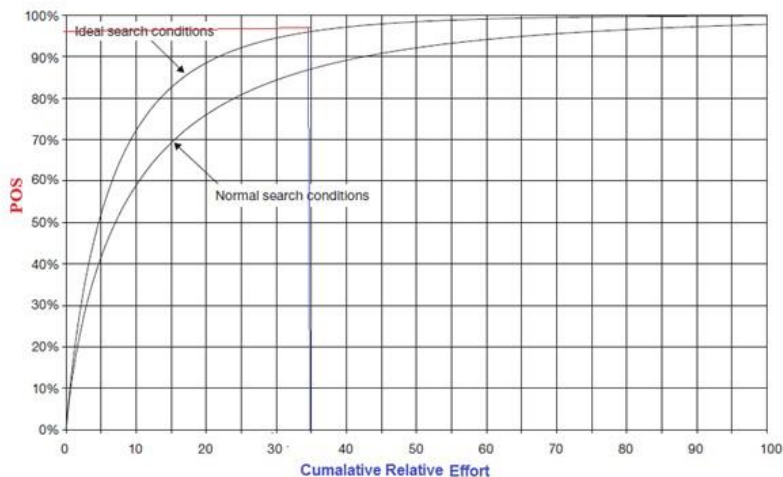
"Mission Co-Ordination." The Probability of Detection (POD) can be estimated from Figure 8 provided in IAMSAR Vol. II and the Probability of Success (POS) value of the action can be determined from Figure 8 and Figure 9.

Figure 8. *POD determination*
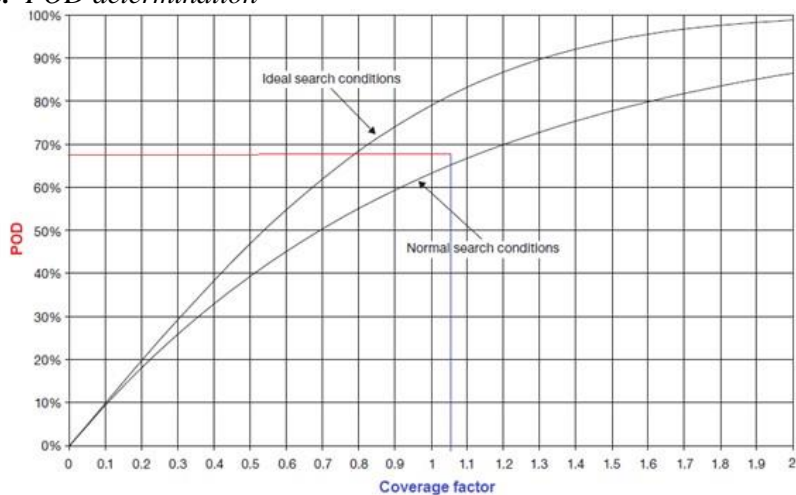
Source: *Own creation.*

**Figure 9.** *POS determination*

Source: *Own creation.*

Diagrams shown in Figures 8 and 9 show our planned SAR operation about ideal search conditions. When the results of the planned activities are not acceptable, it is possible to verify other possibilities of searching for an object in danger.

Suppose we are limited by severe weather conditions caused by strong winds. In that case, the SAR Module program allows us to adjust other action parameters (e.g.,

choosing a different search pattern, using other available rescue facilities), to obtain optimal (acceptable) POS and POD results. The final information of the planned operation is displayed in the Rescue Operation Report window (Figure 10). It is presented in the form of a SAR report, which provides basic information about the scenario.

Figure 10. *Report of planned SAR operation.*
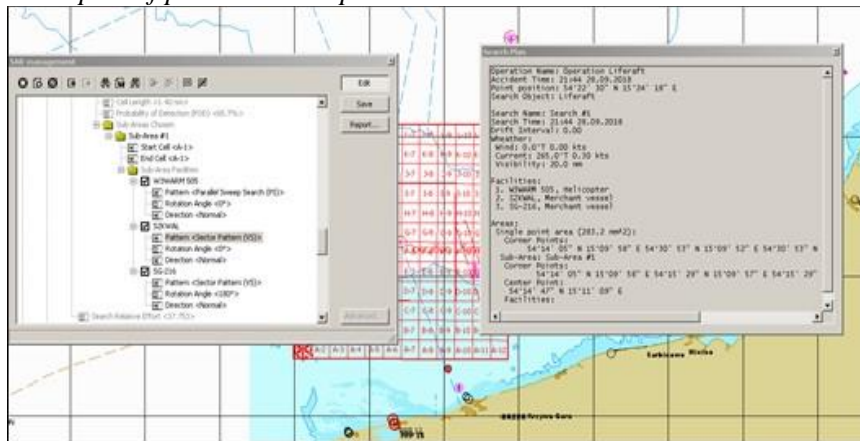
Source: *Own creation.*

5. Conclusions

Planning an effective rescue operation is a subject of many factors. This paper describes that the effectiveness of the SAR operation depends primarily on the accuracy of the information received and the conditions on the scene. Weather conditions and time of day affect the outcome of a successful SAR action. The operator must decide on the specific search pattern, the size of the searched area, and the appropriate selection of available rescue facilities. Thanks to the SAR module of the Navi-Harbour system, which uses the probability theory, it is possible to plan this type of action relatively quickly and modify individual parameters of the action.

Percentage calculation of the probability of success and finding an object in distress affects the success of SAR operation. Described dependencies between automatically calculated POS and POD about wind strength (life raft drift) allows to choose the appropriate amount of available rescue equipment and search patterns. Application of this type of solution accelerates the way of SAR action.

Finding the life raft in distress depends mainly on a professionally planned SAR operation. The determining factor of the effectiveness of such a process depends on used SAR equipment and the knowledge of the reference point. The tested object (life raft) was more affected by the wind parameter than the current at the Baltic region. The program calculates the POD of the searched object and information about the effectiveness of the planned SAR operation. It allows for a quick analysis of the

selection of available SAR equipment for the action by simulating several variants, which will provide the highest probability of success. These actions directly reflect the efficiency of the rescue operation and increase the level of safety at sea.

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